Docket No. 984 PATENT

Commissioner of Patents and Trademarks
Washington, D.C. 20231

NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of
Inventor(s):

WARNING: *Patent must be applied for in the name(s) of all of the actual inventor(s). 37 CFR 1.41(a) and 1.53(b).*

For (title): CD-40 Binding Molecules and CTL Peptides for Treating Tumors

1. Type of Application

This new application is for a(n) (*check one applicable item below*):

- [X] Original
- [ ] Design
- [ ] Plant

WARNING: *Do not use this transmittal for a completion in the U.S. of an International Application under 35 U.S.C. 371(c)(4) unless the International Application is being filed as a divisional, continuation or continuation-in-part application.*

NOTE: If one of the following 3 items apply then complete and attach ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF A PRIOR U.S. APPLICATION CLAIMED.

- [ ] Divisional
- [ ] Continuation
- [ ] Continuation-in-part (CIP)

CERTIFICATION UNDER 37 CFR 1.10

I hereby certify that this New Application Transmittal and the documents referred to as enclosed therein are being deposited with the United States Postal Service on this date _____ in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number _____ addressed to the: Commissioner of Patents and Trademarks, Washington, D.C. 20231.,

_____
(Type or print name of person mailing paper)

_____
(Signature of person mailing paper)

*NOTE: **Each** paper or fee referred to as enclosed herein has the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 CFR 1.10(b).*

8. Assignment

☒ An assignment of the invention to ~~The Un~~ Tarot Inc. & The University of Texas

☐ is attached.

☒ will follow.

9. Certified Copy

Certified copy(ies) of application(s)

(country)	(appln. no.)	(filed)
(country)	(appln. no.)	(filed)
(country)	(appln. no.)	(filed)

from which priority is claimed

☐ is(are) attached.

☐ will follow.

*Note: The foreign application forming the basis for the claim for priority **must** be referred to in the **oath** or **declaration**. 37 CFR 1.55(a) and 1.63.*

NOTE: This item is for any foreign priority for which the application being filed directly relates. If any parent U.S. application or International Application from which this application claims benefit under 35 U.S.C. 120 is itself entitled to priority from a prior foreign application then complete item 18 on the ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

10. Fee Calculation (37 CFR 1.16)

A. ☐ Regular application

CLAIMS AS FILED

Number filed	Number Extra	Rate	Basic Fee
			~~$370.00~~ 380.00
Total Claims 1 −20=		X	$ 12.00	0
Independent Claims (37 CFR 1.16(b)) 5 −3=	2	X	$ ~~36.00~~ 39.00
Multiple dependent claim(s), if any (37 CFR 1.16(d))			$120.00

☐ Amendment cancelling extra claims enclosed.

☐ Amendment deleting multiple dependencies enclosed.

☐ Fee for extra claims is not being paid at this time.

NOTE: If the fees for extra claims are not paid on filing they must be paid or the claims cancelled by amendment, prior to the expiration of the time period set for response by the Patent and Trademark Office in any notice of fee deficiency. 37 CFR 1.16(d).

Filing Fee Calculation $ 572.00

B. ☐ **Design application**
($150.00—37 CFR 1.16(f))

Filing Fee Calculation $ _____

C. ☐ **Plant application**
($250.00—37 CFR 1.16(g))

Filing fee calculation $ _____

11. Small Entity Statement(s)

☒ Verified Statement(s) that this is a filing by a small entity under 37 CFR 1.9 and 1.27 is(are) attached.

Filing Fee Calculation (50% of **A, B** or **C** above) $ _____

NOTE: Any excess of the full fee paid will be refunded if a verified statement and a refund request are filed within 2 months of the date of timely payment of a full fee. 37 CFR 1.28(a).

12. Request for International-Type Search (37 CFR 1.104(d)) *(complete, if applicable)*

☐ Please prepare an international-type search report for this application at the time when national examination on the merits takes place.

13. Fee Payment Being Made At This Time

☐ Not Enclosed

☐ No filing fee is to be paid at this time. (*This and the surcharge required by 37 CFR 1.16(e) can be paid subsequently.*)

☒ Enclosed

☒ basic filing fee $ 572.00

☐ recording assignment ($8.00; 37 CFR 1.21(h)) $ _____

☐ petition fee for filing by other than all the inventors or person on behalf of the inventor where inventor refused to sign or cannot be reached. ($120.00; 37 CFR 1.47 and 1.17(h)) $ _____

☐ for processing an application with a specification in a non-English language. ($30.00; 37 CFR 1.52(d) and 1.17(k) $ _____

☐ processing and retention fee ($120.00; 37 CFR 1.53(d) and 1.21(l))

☐ fee for international-type search report ($30.00; 37 CFR 1.21(e)). $ _____

NOTE: 37 CFR 1.21(l) establishes a fee for processing and retaining any application which is abandoned for failing to complete the application pursuant to 37 CFR 1.53(d) and this, as well as the changes to 37 CFR 1.53 and 1.78, indicate that in order to obtain the benefit of a prior U.S. application, either the basic filing fee must be paid or the processing and retention fee of § 1.21(l) must be paid within 1 year from notification under § 53(d).

Total fees enclosed $ 572.00

14. Method of Payment of Fees

☒ Check in the amount of $ 572.00

☒ Charge Account No. 20-0057 in the amount of $ X. A duplicate of this transmittal is attached.

NOTE: Fees should be itemized in such a manner that it is clear for which purpose the fees are paid. 37 CFR 1.22(b).

15. Authorization to Charge Additional Fees

WARNING: *If no fees are to be paid on filing the following items should not be completed.*

WARNING: *Accurately count claims, especially multiple dependent claims, to avoid unexpected high charges, if extra claim charges are authorized.*

☒ The Commissioner is hereby authorized to charge the following additional fees by this paper and during the entire pendency of this application to Account No. 20-0057 :

☒ 37 CFR 1.16(a), (f) or (g) (filing fees)

☒ 37 CFR 1.16(b), (c) and (d) (presentation of extra claims)

NOTE: Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 CFR 1.16(d)), it might be best not to authorize the PTO to charge additional claim fees, except possibly when dealing with amendments after final action.

☒ 37 CFR 1.16(e) (surcharge for filing the basic filing fee and/or declaration on a date later than the filing date of the application)

☒ 37 CFR 1.17 (application processing fees)

WARNING: *While 37 CFR 1.17(a), (b), (c) and (d) deal with extensions of time under § 1.136(a) this authorization should be made only with the knowledge that: "Submission of the appropriate extension fee under 37 C.F.R. 1.136(a) is to no avail unless a request or petition for extension is filed." (Emphasis added). Notice of November 5, 1985 (1060 O.G. 27).*

☒ 37 CFR 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 CFR 1.311(b))

NOTE: Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of allowance. 37 CFR 1.311(b).

NOTE: 37 CFR 1.28(b) requires "Notification of any change in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying, . . . issue fee". From the wording of 37 CFR 1.28(b): (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.

16. Instructions As To Overpayment

☒ credit Account No. 20-0057

☐ refund

Reg. No. 31,211

Tel. No. (713) 664 2288

SIGNATURE OF ATTORNEY

ERIC MIRABEL

Type or print name of attorney

TAYLOR, DUNC 10301 Stella Link

P.O. Address

Houston TX 77025

(Application Transmittal [4-1]—page 6 of 7)

2. Benefit of Prior U.S. Application(s) (35 USC 120)

NOTE: If the new application being transmitted is a divisional, continuation or a continuation-in-part of a parent case, or where the parent case is an International Application which designated the U.S., then check the following item and complete and attach ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

☐ The new application being transmitted claims the benefit of prior U.S. application(s) and enclosed are ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

3. Papers Enclosed Which Are Required For Filing Date Under 37 CFR 1.53(b) (Regular) or 37 CFR 1.153 (Design) Application

_____ Pages of specification

_____ Pages of claims

_____ Pages of Abstract

_____ Sheets of drawing

☐ formal

☐ informal

WARNING: *DO NOT submit original drawings. A high quality copy of the drawings should be supplied when filing a patent application. The drawings that are submitted to the Office must be on strong, white, smooth, and non-shiny paper and meet the standards according to § 1.84. If corrections to the drawings are necessary, they should be made to the original drawing and a high-quality copy of the corrected original drawing then submitted to the Office.* ***Only one copy is required or desired.*** *Comments on proposed new 37 CFR 1.84. Notice of March 9, 1988 (1990 O.G. 57-62).*

NOTE: "Identifying indicia such as the serial number, group and unit, title of the invention, attorney's docket number, inventor's name, number of sheets, etc., not to exceed 2¾ inches (7.0 cm.) in width may be placed in a centered location between the side edges within three fourths inch (19.1 mm.) of the top edge. Either this marking technique on the front of the drawing or the placement, although not preferred, of this information and the title of the invention on the back of the drawings is acceptable." Proposed 37 CFR 1.84(1). Notice of March 9, 1988 (1090 O.G. 57-62).

4. Additional papers enclosed

☐ Preliminary Amendment

☐ Information Disclosure Statement

☒ Form PTO-1449

☐ Citations

☐ Declaration of Biological Deposit

☐ Authorization of Attorney(s) to Accept and Follow Instructions from Representative

☐ Special Comments

☐ Other

5. Declaration or oath

☒ Enclosed

executed by *(check **all** applicable boxes)*

☐ inventor(s).

☐ legal representative of inventor(s). 37 CFR 1.42 or 1.43

☐ joint inventor or person showing a proprietary interest on behalf of inventor who refused to sign or cannot be reached.

☐ this is the petition required by 37 CFR 1.47 and the statement required by 37 CFR 1.47 is also attached. *See item 13 below for fee.*

☒ Not Enclosed.

WARNING: *Where the filing is a completion in the U.S. of an International Application but where a declaration is not available or where the completion of the U.S. application contains subject matter in addition to the International Application the application may be treated as a continuation or continuation-in-part, as the case may be, utilizing ADDED PAGE FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION CLAIMED.*

☐ Application is made by a person authorized under 37 CFR 1.41(c) on behalf of *all* the above named inventor(s). The declaration or oath, along with the surcharge required by 37 CFR 1.16(e) can be filed subsequently.

Note: *It is important that **all** the correct inventor(s) are named for filing under 37 CFR 1.41(c) and 1.53(b).*

☐ Showing that the filing is authorized. *(Not required unless called into question. 37 CFR 1.41(d).*

6. Inventorship Statement

WARNING: *If the named inventors are each not the inventors of all the claims an explanation, including the ownership of the various claims at the time the **last** claimed invention was made, should be submitted.*

The inventorship for all the claims in this application are:

☒ The same

or

☐ Are not the same. An explanation, including the ownership of the various claims at the time the **last** claimed invention was made,

☐ is submitted.

☐ will be submitted.

7. Language

NOTE: An application including a signed oath or declaration may be filed in a language other than English. A verified English translation of the non-English language application and the processing fee of $30.00 required by 37 CFR 1.17(k) is required to be filed with the application or within such time as may be set by the Office. 37 CFR 1.52(d).

NOTE: A non-English oath or declaration in the form provided or approved by the PTO need not be translated. 37 CFR 1.69(b).

☒ English

☐ non-English

☐ the attached translation is a verified translation. 37 CFR 1.52(d).

A

PATENT

Attorney's Docket No. 98-4

Serial or Patent No.:

File or Issued: herewith

For: CD40 Binding Molecules and CTL Peptides for Treating Tumors

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37CFR 1.9(f) and 1.27(c)) - SMALL BUSINESS CONCERN

I hereby declare that I am an official of the small business concern empowered to act on behalf of the concern identified as Tanox, Inc., 10301 Stella Link, Houston, Texas 77025.

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third-party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed, to and remain with the small business concern identified above with regard to the invention, entitled

CD40 Binding Molecules and CTL Peptides for Treating Tumors

BY: Cornelis J.M. Melief;
Rienk Offinga;
Rene Toes;
Stephen P. Schoenberger; and
Mark deBoer

described in the specification filed herewith.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern

under 37 CFR 1.9(d) or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small business entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

David Duncan, Jr.
Vice President,
Tanox, Inc.
10301 Stella Link
Houston Texas 77025

May 21, 1999
Date

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CD40 BINDING MOLECULES AND CTL PEPTIDES FOR TREATING TUMORS

Field of the Invention

The invention includes CD40 binding molecules together with CTL-activating peptides, including tumor antigens, in a pharmaceutical composition.

Background of the invention

Many tumors escape surveillance by our immune system. In cancer patients there is clearly a quantitative and/or qualitative defect in the immune system's specific mechanisms to delete tumor cells. One of these mechanisms is provided by the cytotoxic T cells (CTL) that can recognise and kill cells infected by virus or transformed into cancer cells. Previously it was postulated that dendritic cells (DC) stimulate T-helper cells which, in turn, provide help for the activation of CTL. The present inventors have demonstrated that the T-helper cell is not providing helper signals directly to the CTL (by secretion of IL2), but rather, the T-helper cell is providing a signal to the DC that induces yet uncharacterised cell surface and/or soluble molecules that can activate CTL in the absence of T-helper cells. The signal provided by the T-helper cell to the DC is mediated by CD40L-CD40 interaction. This novel finding has provided an unique opportunity for cancer immunotherapy.

The immune system is capable of killing autologous cells when they become infected by virus or when they transform into cancer cells. Such a potentially dangerous mechanism must, clearly, be under tight control. The immune system's CTL circulate as

inactive precursors. To be activated, the precursor T-killer cell must recognise its specific antigen peptide, which is presented as MHC class I molecules on professional APC. However, in order to prime these T cells, the APC also need to present the antigen in a proper costimulatory context as provided by, amongst others, the costimulatory surface molecules B7.1 and B7.2 and by the lympokine IL-12.

Until recently it was believed that a T-helper cell that recognises the same antigen on the same APC is needed to fully activate the CTL. The specific T-helper cell would supply cytokines such as IL-2 needed for the activation of the CTL. Guerder and Matzinger (J. Exp. Med. 176:553 (1992)), however, proposed the "licensing" model for CTL activation. In this model it was suggested that the T-helper cell, when recognising its antigen on a professional APC, would deliver an activation signal to the APC that as a result would be able to subsequently activate a CTL without the need for the T-helper cell to be present. Only very recently, the molecular mechanism of the licensing model has been elucidated. Schoenberger et al. (Nature 393:480 (1998)), described the role of the CD40L-CD40 pathway in the licensing model. Interaction between T-helper cell and DC through the CD40-CD40L binding results in activation of the DC, thereby enabling the DC to efficiently prime naive CTL.

DC circulate through the tissues of our body and in this manner can collect, process and present antigens. After collection of antigens, they migrate to the draining lymph nodes where they present antigen to the T cells. It is well known that a DC needs to be activated to perform optimally. Resting DC express only modest levels of MHC and costimulatory molecules and are poor stimulators of T cells. DC can be activated by

inflammatory cytokines and bacterial products, which results in upregulation of MHC and costimulatory molecules. Activation of DC into fully mature DC, expressing optimal levels of MHC molecules, costimulatory molecules and lymphokines such as IL-12, requires additional triggering of these cells through the CD40 receptor. Consequently, the combination of inflammatory cytokines at the site of antigen uptake and the CD40L-CD40 interaction during the T-helper cell interaction result in an optimal capacity to license the DC for CTL activation.

Many tumors escape immune surveillance by specific CTL mechanisms. If DC gather tumor antigens under non-inflammatory conditions the number of T-helper cells that are activated may be to low to induce enough CTL to be activated to induce an appropriate anti-tumor response. This concept has prompted investigators to help the immune system by administration of cytokines such as IL-2 and IL-12 that directly stimulate CTL activity or by boosting antigen presentation by administration of tumor cells transfected with GM-CSF. These strategies have met variable but encouraging results.

It is clear that there is still a great need to find ways to generate and/or enhance protective anti-tumor responses involving cellular and humoral immunity. The CD40 activation pathway was found to be a major immunoregulatory pathway for the generation of primary humoral and cellular immune responses. As described above, the CD40 pathway on DC is responsible for the induction of anti-tumor CTL responses. In addition, activation of the CD40 pathway on macrophages stimulates a strong tumoricidal activity.

Summary of the Invention

The invention includes CD40 binding molecules together with CTL-activating peptides, including tumor antigens, in a pharmaceutical composition. Such composition is useful for enhancing the anti-tumor effect of a peptide tumor vaccine, or for otherwise activating CTLs so that the activated CTLs can act against tumorous or infected cells. The CD40 binding molecules can include antibody molecules, as well as homologues, analogues and modified or derived forms thereof, including immunoglobulin fragments like Fab, $(Fab')_2$ and Fv, as well as small molecules including peptides, oligonucleotides, peptidomimetics and organic compounds which bind to CD40 and activate the CTL response. CTL-activating peptides include the adenovirus-derived E1A peptide, having the sequence SGPSNTPPEI (SEQ ID NO:2), and the HPV16 E7 peptide derived from human papillomavirus type 16, having the sequence RAHYNIVTF (SEQ ID NO:3).

The CD40 binding molecule and the CTL activating peptide can be administered to a patient by suitable means, including injection, or gene constructs encoding such a molecule and a peptide can be administered, and the molecule and peptide thereby produced *in vivo* or *ex vivo.* Such a gene therapy is conducted according to methods well known in the art. If the transfection or infection of the gene constructs is done *ex vivo*, the infected or transfected cells can be administered to the patient, or these steps can be done *in vivo* whereby the molecule and the peptide are produced endogenously. The transfection or infection, if done *ex vivo,* can be by conventional methods, including electroporation, calcium phosphate transfection, micro-injection or by incorporating the gene constructs into suitable liposomes. Vectors, including a retrovirus, adenovirus or a

parvovirus vector, or plasmids, can be used to incorporate the gene constructs, which are then expressed *in vivo* or *ex vivo.*

It is demonstrated herein that T-cell help for CTL priming is mediated through CD40-CD40Ligand (CD40L) interactions, and that lack of CTL priming in the absence of $CD4^+$ T cells can be restored by monoclonal antibody (mAb)-mediated CD40 activation of bone marrow-derived APC in the presence of CTL-activating peptides including tumor antigens. Furthermore, blockade of CD40L, expressed by $CD4^+$ T cells, results in the failure to raise CTL immunity. This defect can be overcome by *in vivo* CD40-triggering. I*n vivo* triggering of CD40 can markedly enhance the efficacy of peptide-based anti-tumor vaccines, or otherwise activate CTLs to result in an anti-tumor or anti-infected cell reaction.

It is also noted that a CTL-activating peptide can become tolerogenic, meaning that the host reaction against cells expressing such peptide is inhibited, in the absence of anti-CD40. However, such a peptide combined with an activating anti-CD40 antibody converts tolerization into strong CTL activation. Moreover, as noted above, CD40-ligation can provide an already protective tumor-specific peptide-vaccine with the capacity to induce therapeutic CTL immunity in tumor-bearing mice.

These findings together demonstrate that the CD40-CD40Ligand pair acts as a switch determining whether naive peripheral CTL are primed or tolerized, Therefore CD40-binding agents such as monoclonal antibodies and other stimulatory ligands can be effectively used in combination with a CTL-activating peptide.

Brief description of the Figures

Figure 1: Cross-priming of E1B-specific CTLs requires $CD4^+$ T helper cells

Splenocytes from normal (***a***) or CD4-depleted B6 (***b***) mice immunized with Ad5E1-BALB/c MECs were tested at various effector/target ratios for lysis of syngeneic MEC target cells loaded with the $E1B_{192-200}$ peptide (solid lines), which is derived from human adenovirus and has the sequence VNIRNCCYI (SEQ ID NO:1)or a D^d-restricted control peptide HPV-16 $E7_{49-57}$ (dashed lines). Each line represents one mouse. Data shown represent one experiment of three performed with similar results.

Figure 2: CD40 activation replaces $CD4^+$ T helper cells

Splenocytes from CD4-depleted (***a, b***) or classII-deficient I-Ab-knockout (KO) (***c,d***) B6 mice were immunized with Ad5E1-BALB/c MECs and treated with either the CD40-activating antibody (Ab) FGK45 (***a, c***) or an isotype control antibody (***b, d***). These splenocytes were tested for E1B-specific CTL activity on syngeneic MEC target cells loaded with either the $E1B_{192-200}$ peptide (solid lines) or the HPV-16 $E7_{49-57}$ control peptide (dashed lines). Each line represents a single mouse. Data depicted are from two independent experiments. E/T ratio, effector/target ratio.

Figure 3: B cells are not essential as cross-priming APCs or for anti-CD40-mediated restoration of cross-priming

Spenocytes were taken from untreated (***a***), CD4-depleted B-cell-deficient B6 MT mice (***b***, ***c***), which were immunized with Ad5E1-BALB/c MECs and which received either an isotype control antibody (***b***) or the CD40-activating antibody FGK45 (***c***). These splenocytes were tested for E1B-specific CTL activity on syngeneic MEC target cells loaded with either the $E1B_{192-200}$ peptide (solid lines) or the HPV $E7_{49-57}$

control peptide (dashed lines). Each line represents one mouse. Data shown represent one experiment of two performed with similar results.

Figure 4: CD40L blockade prevents cross-priming of E1B-specific CTLs

Splenocytes were taken from B6 mice immunized with Ad5E1-BALB/c MECs and treated with the CD40L-blocking antibody MR-1 (***a***), or control antibody (***b***), or from mice treated with the CD40L-blocking antibody MR-1 in combination with the CD40-activating antibody FGK45 (***c***) 24h after immunization. These splenocytes were tested for E1B-specific CTL activity on syngeneic MEC target cells loaded with the $E1B_{192-200}$ peptide (solid lines) or the HPV-16 $E7_{49-57}$ control peptide (dashed lines). Each line represents one mouse. Data shown represent one experiment of three performed with similar results. E/T ratio, effector/target ratio.

Figure 5: Mice injected s.c. with the E1A-peptide are no longer able to mount E1A-specific CTL

C57BL/6 mice were injected twice s.c. (1 week interval) with 20 μg E1A-peptide (***a***, ***b***) or control-peptide (***c***, ***d***) in IFA, and challenged i.p. 1 day later with SAMB7 (***b***, ***d***), a cell line expressing high amounts of E1A-peptide. Bulk cultures derived from these mice were tested for E1A-specific cytotoxicity on target cells pulsed with the E1A-peptide (-■-) or the HPV16 E7-peptide (-O-). Specific lysis of representative bulk cultures at different effector to target (E/T) ratios is shown. This experiment has been repeated 4 times with comparable results.

Figure 6: Tolerizing E1A-peptide is rapidly distributed systemically after s.c. injection in IFA

Spleen cells derived from untreated C57BL/6 mice *(-),* or from mice injected s.c. 16 h earlier with 100 μg of E1A- or HPV16 E7-peptide in IFA were used as stimulator cells for an E1A-specific CTL clone. [^{3}H]-thymidine incorporation (cpm) +/- *S.E.M.* is shown for different effector to stimulator concentrations, without subtraction of background counts. Results are representative of 5 independent experiments.

Figure 7: CTL-tolerance induction is reverted into CTL-priming after CD40-triggering *in vivo*

Wild type C57BL/6 mice (***a***, ***b***) and H-2^b CD40 $^{-/-}$ mice (***c***, ***d***) were injected s.c. with 20 μg E1A-peptide in IFA alone *(**c**)*, in combination with a rat IgG2a control antibody *(**a**)* , or in combination with the anti-CD40 mAb FGK-45 (***b***, ***d***). Bulk cultures from these mice were tested for E1A-specific cytotoxicity on target cells pulsed with the E1A-peptide (-■-), the HPV16 E7-peptide (-O-) or Ad5E1 transformed tumor cells (-◆-). Specific lysis of representative bulk cultures at different E/T ratios is shown. This experiment has been repeated 18 (B6 mice) and 2 (CD40-/- mice) times, respectively, with comparable results. In (***e***) the % specific lysis of 23 respectively 37 bulk CTL cultures derived from B6 mice injected with E1A-peptide in IFA alone (left) or in combination with the anti-CD40 mAb (right) at an E/T of 60 is shown. Mean plus standard deviation of each group are shown (E1A versus E1A+anti-CD40: $p<0.01$, student t-test).

Figure 8: Therapy of HPV16 E6 and E7 transformed cells by combination treatment of peptide together with *in vivo* CD40 triggering

Mice were injected s.c with 25.000 HPV16 transformed syngeneic cells (TC-1). C57BL/6 mice were left untreated (-○-) or after 6 days received 100 μg HPV16 E7-peptide i.p. in IFA (-□-), 100 μg HPV16 E7-peptide i.p. in IFA in combination with the anti-CD40 mAb FGK-45 (-■-) or a control peptide i.p. in IFA in combination with the anti-CD40 mAb FGK-45 (-●-). The percentage of tumor bearing mice is depicted for different treatment groups (n=10) in (***a***). The differences between the group treated with the HPV16-peptide plus the anti-CD40 mAb and the other three groups were statistically significant ($p<0.01$) (Log-Rank test). In (***b***) the percentage of surviving animals is shown (E7-peptide-treated group vs E7-peptide plus anti-CD40-treated group: $p = 0.002$, Log-Rank test).

Making and Using the Invention

The CD40 binding molecules of the invention can be made by conventional production and screening techniques. A rat and a hamster anti-mouse CD40 monoclonal antibody ("Mabs") are each described in *Nature* 393: 474-77 (1998) and are available commercially (Pharmingen, Inc., CA). The anti-mouse CD40 MAb, designated FGK45, which is used in the experiments described below, is described by Rolink. A. *et al., Immunity* 5, 319-330 (1996). Anti-human CD40 MAbs can be made following techniques well-known in the art, and described by G. Köhler and C. Milstein (*Nature*, 1975: 256: 495-497). MAbs can be raised by immunizing rodents (*e.g.* mice, rats, hamsters and guinea pigs) with either native CD40 as expressed on cells or purified from human plasma or urine, or recombinant CD40 or its fragments, expressed in a eukaryotic or prokaryotic system. Other animals can be used for immunization, *e.g.* non-human

primates, transgenic mice expressing human immunoglobulins and severe combined immunodeficient (SCID) mice transplanted with human B lymphocytes. Hybridomas can be generated by conventional procedures by fusing B lymphocytes from the immunized animals with myeloma cells (e.g. Sp2/0 and NS0), as described by G. Köhler and C. Milstein *Id.* In addition, anti-CD40 MAbs can be generated by screening of recombinant single-chain Fv or Fab libraries from human B lymphocytes in phage-display systems. The specificity of the MAbs to CD40 can be tested by enzyme linked immunosorbent assay (ELISA), Western immunoblotting, or other immunochemical techniques. The activating activity of the antibodies on CTLs, in combination with a CTL-activating peptide, can be assessed using the assays described in the Examples below.

For treating humans, the anti-CD40 MAbs would preferably be used as chimeric, Deimmunised, humanized or human antibodies. Such antibodies can reduce immunogenicity and thus avoid human anti-mouse antibody (HAMA) response. It is preferable that the antibody be IgG4, IgG2, or other genetically mutated IgG or IgM which does not augment antibody-dependent cellular cytotoxicity (S.M. Canfield and S.L. Morrison, *J. Exp. Med.*, 1991: 173: 1483-1491) and complement mediated cytolysis (Y.Xu et al., *J. Biol. Chem.*, 1994: 269: 3468-3474; V.L. Pulito et al., *J. Immunol.*, 1996; 156: 2840-2850).

Chimeric antibodies are produced by recombinant processes well known in the art, and have an animal variable region and a human constant region. Humanized antibodies have a greater degree of human peptide sequences than do chimeric antibodies. In a humanized antibody, only the complementarity determining regions

(CDRs) which are responsible for antigen binding and specificity are animal derived and have an amino acid sequence corresponding to the animal antibody, and substantially all of the remaining portions of the molecule (except, in some cases, small portions of the framework regions within the variable region) are human derived and correspond in amino acid sequence to a human antibody. See L. Riechmann et al., *Nature*, 1988; 332: 323-327; G. Winter, *United States Patent* No. 5,225,539; C.Queen et al., U.S. patent number 5,530,101.

Deimmunised antibodies are antibodies in which the T and B cell epitopes have been eliminated, as described in in International Patent Application PCT/GB98/01473. They have reduced immunogenicity when applied *in vivo.*

Human antibodies can be made by several different ways, including by use of human immunoglobulin expression libraries (Stratagene Corp., La Jolla, California) to produce fragments of human antibodies (VH, VL, Fv, Fd, Fab, or $(Fab')_2$, and using these fragments to construct whole human antibodies using techniques similar to those for producing chimeric antibodies. Human antibodies can also be produced in transgenic mice with a human immunoglobulin genome. Such mice are available from Abgenix, Inc., Fremont, California, and Medarex, Inc., Annandale, New Jersey.

One can also create single peptide chain binding molecules in which the heavy and light chain Fv regions are connected. Single chain antibodies ("ScFv") and the method of their construction are described in U.S. Patent No. 4,946,778. Alternatively, Fab can be constructed and expressed by similar means (M.J. Evans et al., *J. Immunol. Meth.,* 1995; 184: 123-138). All of the wholly and partially human antibodies are less

immunogenic than wholly murine MAbs, and the fragments and single chain antibodies are also less immunogenic. All these types of antibodies are therefore less likely to evoke an immune or allergic response. Consequently, they are better suited for *in vivo* adminstration in humans than wholly animal antibodies, especially when repeated or long-term adminstration is necessary. In addition, the smaller size of the antibody fragment may help improve tissue bioavailability, which may be critical for better dose accumulation in acute disease indications, such as tumor treatment.

Based on the molecular structures of the variable regions of the anti-CD40 mAbs or the known CTL-activating peptides, one could use molecular modeling and rational molecular design to generate and screen molecules which mimic the molecular structures of the binding region of the antibodies or the peptides, respectively, and activate CTLs. These small molecules can be peptides, peptidomimetics, oligonucleotides, or other organic compounds. The mimicking molecules can be used for treatment of cancers and infections. Alternatively, one could use large-scale screening procedures commonly used in the field to isolate suitable molecules from libraries of compounds.

The dosage for the molecules of the invention can be readily determined by extrapolation from the *in vitro* tests and assays described below, or from animal experiments or from human clinical trials. The molecules of the invention would be preferentially administered by injection, in the case of antibodies or proteins, although certain small molecules may be suited for oral administration. The assays and tests demonstrating the efficacy of the invention are described below.

Example1: Signaling through CD40 can replace $CD4^+$ helper T cells in CTL priming

A well characterized model system to probe the mechanism of T-cell help for the primary activation of CD8+ CTL responses *in vivo* was used. C57BL/6 (with the major histocompatibility complex (MHC) H-2^b) mice immunized with allogenic BALB/c (H-2^d) mouse embryo cells (MECs) expressing the human adenovirus type 5 early region 1 (Ad5EI-BALB/c MECs) generated strong CTL responses against an H-$2D^b$-restricted epitope of the adenovirus EIB protein ($EIB_{192-200}$) (Figure 1a). As the allogeneic H-2^d MHC molecules expressed by the Ad5EI-BALC/c MECs cannot prime H-2^b-restricted host CTLs, generation of E1B-specific CTLs must require cross-priming, that is, the uptake and H-2^b-restricted re-presentation of antigen by host APCs. Cross-priming of EIB-specific CTLs is strictly helper-dependent (Figure 1b), as mice depleted of CD4+ T-helper (T_h) cells before immunization no longer mounted an E1B-specific CTL response.

To investigate whether signalling through CD40 can replace $CD4^+$ helper T cells in CTL priming, mice were depleted of $CD4^+$ T cells *in vivo* before immunization with Ad5E1BALB/c MECs. One day after immunization, the mice received a single injection of the activating antibody anti-mouse CD40 mAb FGK45, or of an isotype-matched control antibody. Administration of FGK45 to CD4-depleted, immunized mice resulted in the efficient restoration of E1B-specific CTL responses (Figure 2a) whereas treatment with the control antibody did not (Figure 2b). Priming of E1B-specific CTLs was not detected in naïve mice treated with FGK45 alone (not shown). To address the possibility that the effect of FGK45 was mediated through remaining $D4^+$ cells that were not depleted by treatment with the anti-CD4 antibody, B6 I-A^b knockout mice, which lack mature functional $CD4^+$ peripheral T cells, were immunized with the Ad5EI-BALB/c MECs. The response to immunization in these mice mirrors that seen in the CD4-

depleted mice, in that E1B-specific CTLs were detectable only in mice receiving the CD40-activating antibody (Figure 2c), and not in those receiving the control antibody (Figure 2d).

It was also studied whether the requirement for anti-CD40 antibodies in priming of CTLs in CD4-depleted mice could be replaced by bacterial lipopolysaccharide (LPS) (50 μg intravenous), a potent inducer of proinflammatory cytokines, or by administration of IL-2 (1×10^5 units in incomplete Freund adjuvant, subcutaneous) following immunization with Ad5EI-BALB/c MECs. Whereas CD4-depleted mice treated with FGK45 exhibited strong E1B-specific CTL activity, neither LPS or IL-2 treatment resulted in detectable CTL priming (not shown).

Ligation of CD40 on B cells upregulates their costimulatory activity, suggesting a role for these cells in the restoration of CTL priming by treatment with CD40 activating antibodies. To address this question, B6 MT mice, which lack mature B cells, were immunized with the allogeneic Ad5EI-BALB/c MECs. Cross-priming of E1B-specific CTLs did not require mature B cells (Figure 3a). However, when depleted of $CD4^+$ cells, the B-cell deficient mice did not generate an E1B-specific CTL response (Figure 3b). Activation through CD40 with the FGK45 monoclonal antibody completely restored the capacity of CD4-depleted MT mice to prime E1B-specific CTLs (Figure 3c). Thus B cells are not required as APCs or accessory cells for cross-priming in this model system, nor are they required for CD40-mediated restoration of cross priming of CTLs in the absence of $CD4^+$ helper T cells. These results demonstrate that activation of bone marrow

derived APC through CD40 can bypass the requirement for $CD4^+$ T-helper cells in the cross-priming of E1B-specific CTLs.

Example 2: Blocking the ability of $CD4^+$ helper T cells to interact with APC through the CD40L-CD40 pathway prevents antigen-specific CTL responses in normal mice

If the CD40L-CD40 interaction represents the physiological pathway used by $CD4^+$ helper T cells to help CTLs, blocking the ability of the $CD4^+$ T cells to interact with APC through CD40L-CD40 interaction would be expected to diminish priming of E1B-specific CTL responses in normal mice. B6 mice were immunized with Ad5E1-BALB/c MECs and then treated with either the CD40L-blocking antibody MR1, or control antibody. Blockade of CD40L results in drastically reduced E1B-specific CTL responses (Figure 4a) compared to the efficient CTL priming seen in mice receiving the control antibodies (Figure 4b). The priming defect induced by CD40L blockade was fully restored following CD40 signalling by FGK45 (Figure 4c). Thus the defect in CTL-priming induced by CD40L blockade lies in the failure of T_H cells to transmit, rather than to receive, CD40L-mediated signals.

Example 3: E1A-specific CTL unresponsiveness after peptide administration

A previously described model system has been used (Toes et al., J. Immunol. 156:3911 (1996)). It has been shown that s.c. vaccination with the Ad5E1A-derived CTL epitope SGPSNTPPEI (SEQ ID NO: 2) in IFA prevents mice from controlling the outgrowth of Ad5E1A-expressing tumors. This indicates that the E1A/IFA vaccine induced suppression rather than induction of E1A-specific CTL immunity. Moreover, administration of the E1A/IFA vaccine to T cell receptor (TCR)-transgenic mice, which

express the TCR α and β chains of an E1A-specific CTL clone, strongly suppressed tumor-specific CTL-mediated immunity. These experiments examined the effects of peptide administration on a monoclonal CTL population. To establish whether s.c. E1A-peptide vaccination also induces E1A-specific CTL tolerance at the polyclonal CTL level, wild type (wt) C57BL/6 mice were injected with either E1A-peptide (Figure 5a and 5b) or a control peptide Figure 5c and 5d). One day later the mice were boosted with a syngeneic cell line expressing high levels of the E1A-peptide at its surface (Figure 5b and 5d). Injection of this cell line into mice primed with the control peptide readily induces E1A-specific immunity (Figure 5d). However, the ability of mice to mount E1A-specific CTL responses was abrogated after injection of the E1A/IFA vaccine (Figure 5b). These data indicate that injection of the E1A-peptide not only leads to E1A-specific tolerance in TCR-transgenic mice but also in mice expressing a polyclonal E1A-specific T cell repertoire.

Since s.c. injection of the E1A/IFA vaccine leads to systemic CTL tolerance, it was investigated whether the E1A-peptide is dispersed systemically and presented to precursor CTL in the periphery. Therefore, mice were injected s.c. with the E1A-peptide or Human Papilloma Virus (HPV) 16 E7-derived control peptide emulsified in IFA. Spleen cells from these mice were isolated 16h later and used as stimulator cells for an E1A-specific CTL clone *in vitro*. Splenocytes from mice injected with the E1A-peptide s.c. induced specific proliferation, whereas splenocytes from mice injected with the E7-peptide s.c. failed to do so (Figure 6). Moreover, a control CTL clone did not proliferate on spleen cells derived from E1A-injected mice (data not shown). Thus, these data

indicate that the E1A-peptide injected s.c. in IFA is systemically presented in the periphery by, amongst others, splenocytes.

In view of the tolerizing effects described above of the E1A-peptide vaccine, there was a question whether CD40-triggering *in vivo* is sufficient to prevent peripheral tolerization of CTL and to restore CTL priming. Therefore, it was investigated whether injection of tolerizing peptides combined with *in vivo* CD40 triggering could prevent the induction of peripheral CTL tolerance leading to tumor-specific CTL immunity.

In Examples 1 and 2 it has been shown that CD40-triggering *in vivo* can replace the requirement for $CD4^+$ T helper cells in priming of helper-dependent CTL responses. Since $CD4^+$ T cell-mediated helper activity has been implicated in the prevention of peripheral CTL tolerance induction, the inventors addressed the question whether CD40-triggering *in vivo* is sufficient to prevent peripheral E1A-specific CTL tolerization. To this end, mice were injected with the E1A/IFA vaccine in combination with the activating anti-CD40 mAb FGK-45. Mice that received this combination mounted strong E1A-specific CTL responses (Figure 7b and 7e), whereas mice that received the E1A/IFA vaccine (Figure 7e) or mAb alone did not (not shown). The combination of E1A/IFA vaccine and anti-CD40 mAb failed to elicit CTL in CD40-deficient mice (Figure 7c and 7d). Furthermore, co-injection of the E1A/IFA vaccine with an isotype-matched control mAb (Figure 6a) or IL-2 failed to convert CTL tolerance induced by the E1A/IFA vaccine into CTL priming (not shown). The range and variation of responses to the E1A-epitope in E1A-peptide only, or E1A-peptide plus anti-CD40-vaccinated animals, is

shown in Figure 7e. Thus, systemic CD40 activation can reverse peptide-induced peripheral CTL tolerance into peptide and tumor-specific CTL mediated immunity.

The induction of E1A-specific immunity strongly correlated with the presence of $CD8^+$ T cells in the spleen of vaccinated mice that stained with PE-conjugated H-2-D^b-tetramers containing the E1A-peptide (D^b/E1A). Within 10 days after vaccination, $CD8^+$ T cells staining with D^b/E1A tetramers could be detected by flow cytometry in mice injected with E1A-peptide and the anti-CD40 mAb, but not in mice injected with E1A-peptide alone (not shown). In the mice injected with E1A-peptide, the percentage of $CD8^+$ cells that stained with the D^b/E1A tetramers was approximately 3%. In mice vaccinated with whole adenovirus, which induces potent E1A-specific immunity, comparable amounts of D^b/E1A tetramer-reactive $CD8^+$ spleen cells were detected. These results indicate that the expansion of E1A-specific $CD8^+$ T cells in mice that received the E1A/IFA vaccine in combination with the anti-CD40 mAb was substantial and equivalent to that found in virus vaccinated animals.

Example 4: CD40-triggering strongly enhances the efficacy of peptide-based anti-cancer vaccines

Although the findings described above show that provision of help through CD40-triggering is sufficient to prevent CTL-tolerization after administration of a tolerogenic peptide-vaccine, they do not address the question whether the efficacy of anti-cancer vaccines that normally induce protective immunity, instead of tolerance, can be enhanced by activation through CD40. It was examined whether CD40-triggering *in vivo* is beneficial to the outcome of vaccination with an HPV16 E7-derived peptide.

Vaccination with this peptide induces protective CTL-mediated immunity against a challenge with HPV16-transformed tumor cells. Moreover, this peptide can be used in a therapeutic setting when loaded on *in vitro* activated DC suggesting that the strength of the anti-tumor response is enhanced when presented by activated DC.

Mice receiving the E7-peptide in combination with CD40-triggering mounted a more potent CTL-response compared to mice treated with E7-peptide only (data not shown), indicating that CD40-triggering also enhances the efficacy of the HPV16 E7-peptide vaccine and confirming the findings with the E1A peptide described above. Moreover, mice treated 6 days after s.c. injection of CD40-negative HPV16 E6/E7 transformed tumor cells with the HPV16 E7-peptide alone (open squares) are able to slow down tumor growth, but eventually most animals succumb to the tumor (Figure 8). When, however, HPV 16 E7-peptide vaccination was combined with injection of the anti-CD40 mAb, tumor growth was markedly reduced and 7 out of 10 mice rejected the tumor, whereas animals injected with a control peptide and the anti-CD40 mAb were unable to control outgrowth of the tumor. These results show that the effect of vaccination regiments can be markedly enhanced when immunization is combined with *in vivo* CD40-triggering. These data provide the basis for the development of extremely potent and novel anti-tumor vaccines for cancer patients.

The foregoing description, terms, expressions and examples are exemplary only and not limiting. The invention includes all equivalents of the foregoing embodiments, both known and unknown. The invention is limited only by the claims which follow and not by any statement in any other portion of this document or in any other source.

WHAT IS CLAIMED IS:

1. A pharmaceutical composition comprising a CD40 binding molecule and a CTL activating peptide.

2. The pharmaceutical composition of claim 1 wherein the CD40 binding molecule is an anti-CD40 antibody or a fragment thereof, a peptide, an oligonucleotide or an organic molecule.

3. The pharmaceutical composition of claim 2 wherein the anti-CD40 antibody is human, humanized, chimeric or Deimmunised™.

4. The pharmaceutical composition of claim 1 wherein the CTL activating peptide is the adenovirus-derived E1A peptide, having the sequence SGPSNTPPEI (SEQ ID NO:1), or the HPV16 E7 peptide derived from human papillomavirus type 16, having the sequence RAHYNIVTF (SEQ ID NO:3).

5. A method of treating tumors comprising administering the pharmaceutical composition of any of claims 1 to 4.

6. A method of treating tumors or infectious diseases comprising administering a CD40 binding molecule and a CTL activating peptide.

7. The method of claim 5 wherein the pharmaceutical composition is administered directly to the tumor.

8. A method of treating tumors or infectious diseases comprising administering gene constructs coding for a CD40 binding molecule and a CTL activating peptide.

9. The method of claim 8 wherein the CD40 binding molecule is an anti-CD40 antibody or a fragment thereof, or a peptide, and the CTL activating peptide is peptide is the adenovirus-derived E1A peptide, having the sequence SGPSNTPPEI (SEQ ID NO:2), or the HPV16 E7 peptide derived from human papillomavirus type 16, having the sequence RAHYNIVTF (SEQ ID NO:3).

10. Cells transfected or infected with the gene constructs of claim 8.

11. The method of claims 8 or 9 wherein transfection or infection of the gene constructs is done *ex vivo* or *in vivo*.

12. The method of claim 11 wherein the transfection is done *ex vivo* by electroporation, calcium phosphate transfection, micro-injection or by incorporating the gene constructs into suitable liposomes.

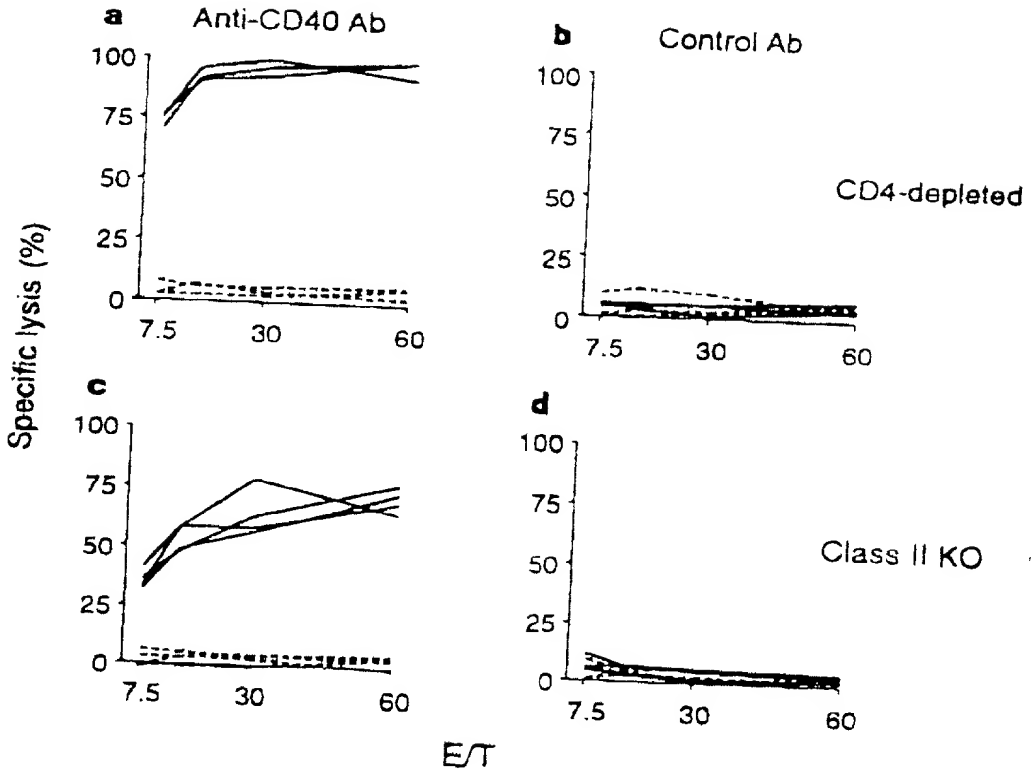
13. The method of claim 12 wherein the infection is done *in vivo* or *ex vivo* by incorporating the gene constructs into a retrovirus, adenovirus or a parvovirus vector, or by incorporating the gene constructs, or the gene constructs with a viral or plasmid vector, into a suitable liposome.

Abstract of the Disclosure

Disclosed is a method and composition for treating tumors or infectious diseases, wherein the composition includes CD40 binding molecules together with CTL-activating peptides, *e.g.,* tumor antigens. Such composition is useful for enhancing the anti-tumor effect of a peptide tumor vaccine, or for otherwise activating CTLs so that the activated CTLs can act against tumorous or infected cells. The CD40 binding molecules can include antibody molecules, as well as homologues, analogues and modified or derived forms thereof, including immunoglobulin fragments like Fab, $(Fab')_2$ and Fv, as well as other molecules including peptides, oligonucleotides, peptidomimetics and organic compounds which bind to CD40 and activate the CTL response.

Specific lysis (%)
a
Normal
b
CD4-depleted
0
25
50
75
100
7.5
30
60
E/T

Figure 1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Anti-CD40 Ab
b
Control Ab
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Class II KO
Specific lysis (%)
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50
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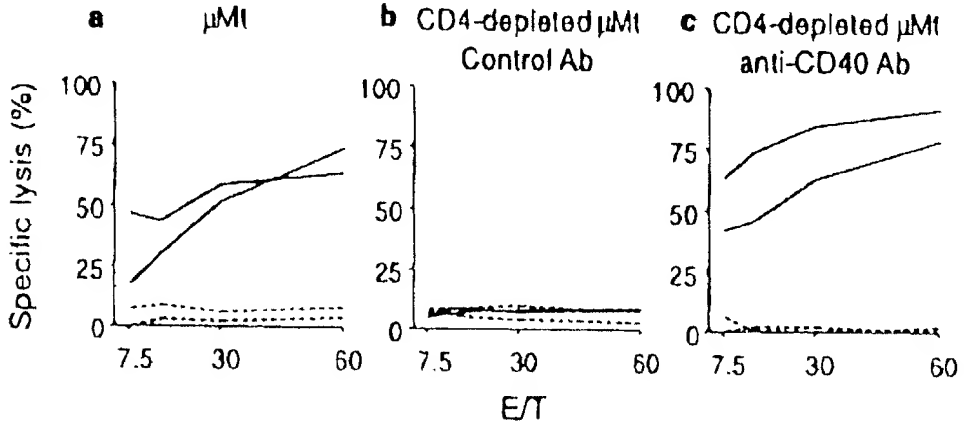
30
60
E/T

Figure 3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μMt
b
CD4-depleted μMt
Control Ab
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Specific lysis (%)
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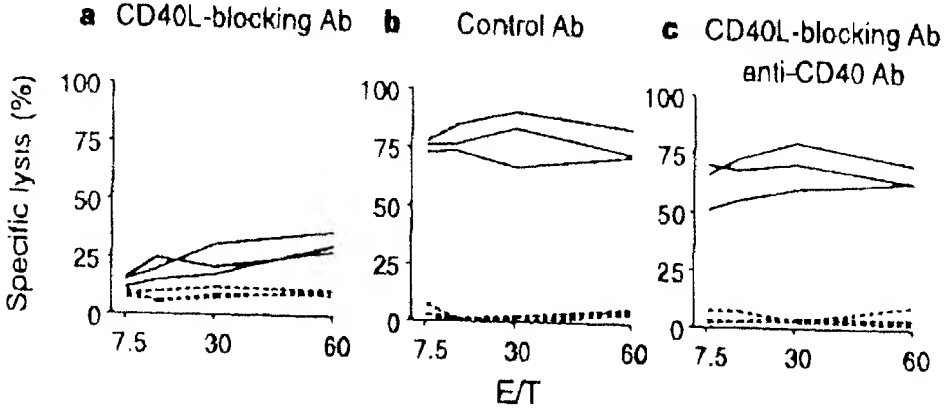
75
50
25
0
7.5
30
60
E/T

Figure 13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anti-CD40 Ab
Specific lysis (%)
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75
50
25
0
7.5
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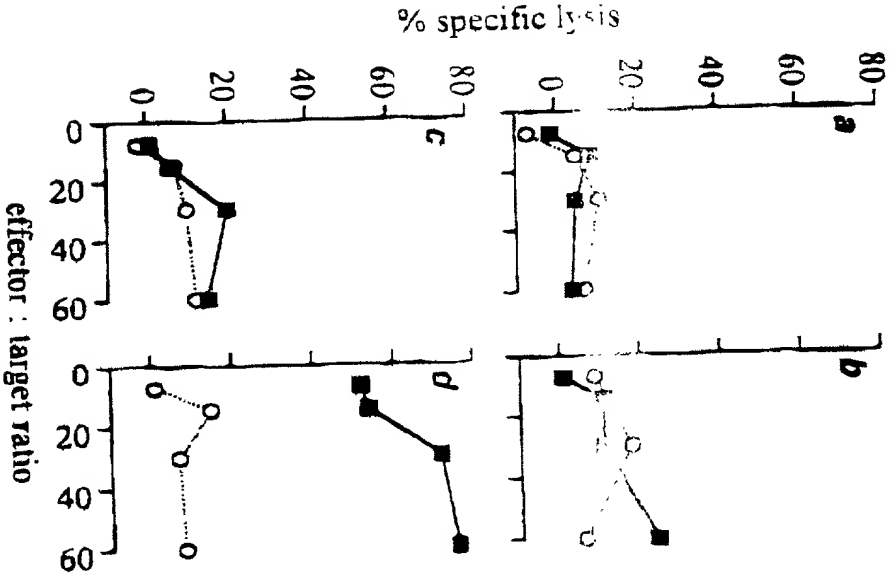
60
E/T

Fig. 4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20
40
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a
d
b
effector : target ratio
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20
40
60

Figure 5

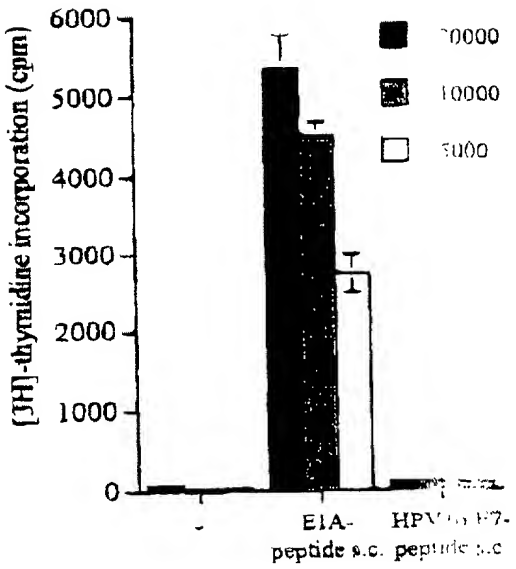

Figure 6

figure 6

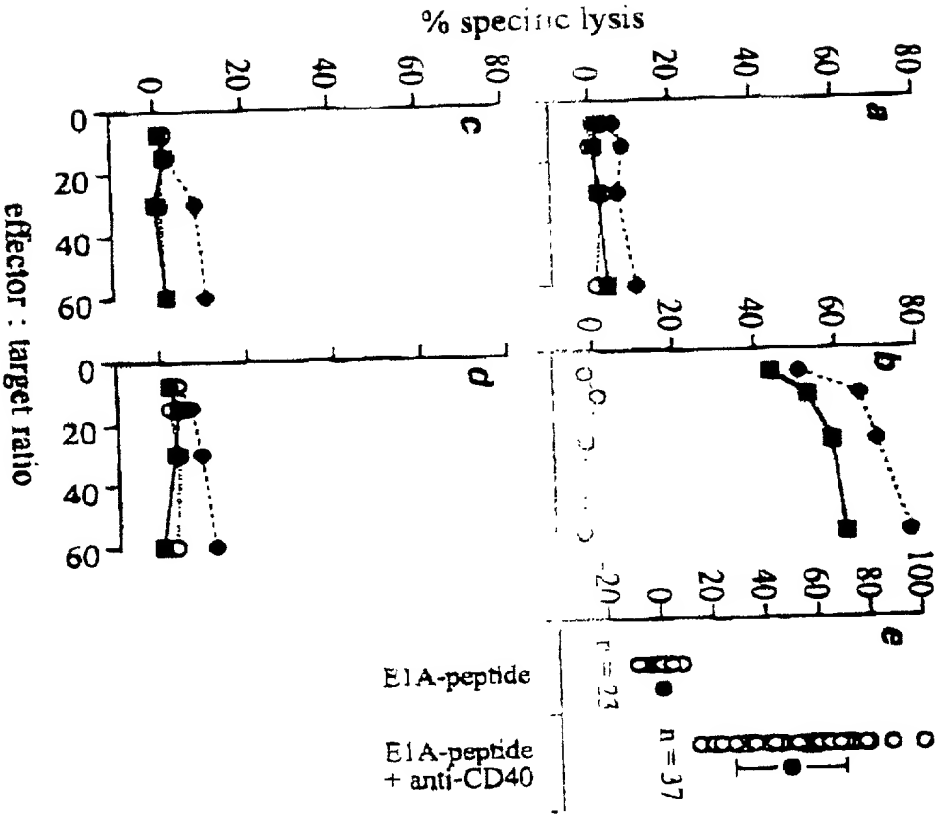

Figure 1

figure 1B

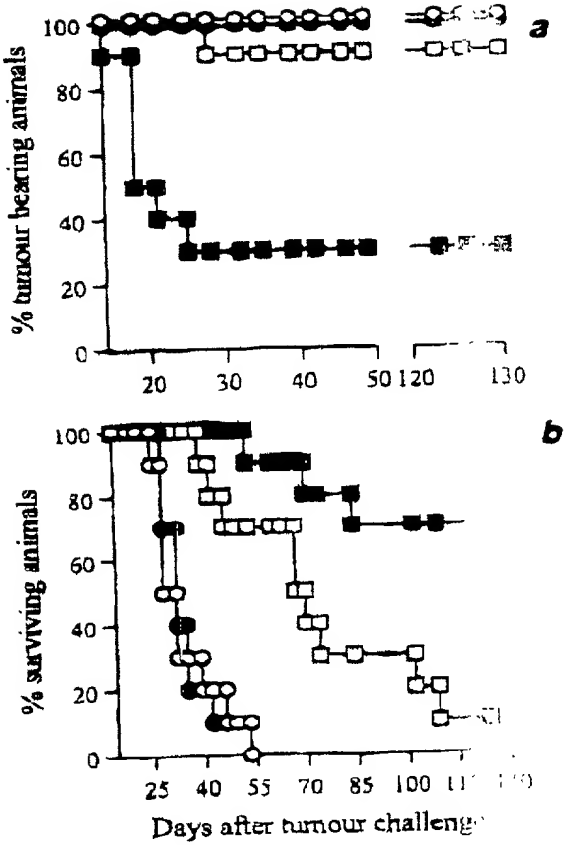

Figure 8

Figure 8

SEQUENCE LISTING

<110> Cornelis J.M. Melief
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<120> CD40 Binding Molecules and CTL Peptides for Treating Tumors

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